Production Planning in a Automotive Press Shop. A model and a Resolution Procedure.

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Abstract

This paper considers the Production Planning Problem in an Automotive Factory Press Shop. The studied Press Shop manufactures something like 300 different body components at its 12 Press Lines. The environment characteristics include a relatively stable demand, high setup times, and limited shared resources like production manpower, setup tooling and teams… To develop a Decision Support System, the mathematical model for such Production Planning Problem has been stablished and a complete resolution methodology has been designed. Different resolution rules for some steps of the Resolution Procedure have been evaluated with real instances of the problem.

1. Introduction

An Automotive Press Shop might be described as a Bi-stage flow-shop [1] where coils (raw material) are first cut into iron plates, ready to be stamped at the matching Press Line. Forecast is known some weeks in advance, although daily demand has a certain variability for most items.

The required resources have a variable availability. Some of them are a real bottleneck, like the setup team, and others are only constraints that must be considered. During the DSS development, the different limited shared resources that appeared were basically: production manpower, racks availability, press lines availability and setup tooling. Moreover, the team devoted to define the Production Plan, took into account circumstances like try-outs, tooling maintenance, stock piling, visits, raw material availability…

The mechanism adopted by the real plant studied consists of a daily planning with a one week horizon, that use to avoid any stock out by maintaining very high stock levels.

Reality in a Press-Shop, like most environments, never occurs as planned: random disruptions, raw material , quality problems, not planned demands, are all events that often happen. Thus the production planning process should react by re-planning. The DSS developed had to take all those problems into account to build a reliable and cheaper plan for the production of body components.

The considered problem is the one named as ELSP (Economic Lot-Sizing Problem); but with scheduling consideration ([2], [3] and [4]) the resolution procedure considers the three Production Planning subfunctions: Loading, Sequencing and Scheduling (as described also in [5]).

The rest of the paper is organised as follows: first the mathematical model used to fully understand the problem. Then the proposed methodology to solve the problem. Lastly, an evaluation of different rules for loading, sequencing and scheduling is introduced.

2. Mathematical model

The objective is to minimize the overall cost, considering setup costs and inventory holding cost. Thus, the mathematical model of the problem described is the following:

$$[MIN]\sum_i M_i CL_i + \sum_i \sum_t h_i S_{i,t} \qquad [0.1.1]$$

Subject to:

$$S_{i,t} = S_{i,t-1} - d_{i,t-1} + p_i \cdot \delta_{i,t} \qquad \forall i,t \qquad [c.1.1]$$

$$\sum_i \varepsilon_{i,t} \cdot g_{i,r} + \sum_i \delta_{i,t} \cdot f_{i,r} \leq DISP_{r,t} \qquad \forall r,t \qquad [c.1.2]$$

$$\delta_{i,t} = 1 \quad si \ \exists m / \ Z_{i,m} + TL_i \leq t \leq Z_{i,m} + TL_i + \frac{Q_{i,m}}{p_i} \qquad \forall i,t \qquad [c.1.3]$$

$$\varepsilon_{i,t} = 1 \quad si \ \exists m / \ Z_{i,m} \leq t \leq Z_{i,m} + TL_i \qquad \forall i,t \qquad [c.1.4]$$

$$S_{i,t} \geq d_{i,t} + SS_i \qquad \forall i,t \qquad [c.1.5]$$

$$S_{i,t} \leq MAX_i \qquad \forall i,t \qquad [c.1.6]$$

$$Z_{i,m} \leq Z_{i,m-1} + TL_i + \frac{Q_{i,m-1}}{p_i} \qquad \forall i, m > 1 \qquad [c.1.7]$$

$$Z_{i,m} \leq H \qquad \forall i, m > 1 \qquad [c.1.8]$$

$$M_i \geq m \qquad \forall i, \ m \ / \ Q_{i,m} > 0 \qquad [c.1.9]$$

$$\delta_{i,t} = \{0,1\} \quad \varepsilon_{i,t} = \{0,1\} \ Z_{i,m}, Q_{i,m} \geq 0 \quad \forall i,m$$

With the following notation:

Sets:		
I ={Products}	**R** ={Resources}	**T** ={Scheduling Periods}
Index:		
i : for products	r : for resources	τ, t : for periods $m(i)$: for set-ups of i
Parameters:		
$d_{i,t}$: demand of product i on t	p_i : i production rate	SS_i : safety stock of product i
CL_i: setup cost of product i	TL_i : setup time of product i.	MAX_i : Maximum i capacity
$g_{i,r}$: Use of r when setting up i	$f_{i,r}$: Use of r when producing i	$DISP_{r,t}$: Availability of Resource r
H : Planning horizon	h_i : holding cost of one unit i during one period	
Variables:		
$Q_{i,m}$: Size of the m-th lot of product i	$Z_{i,m}$: Start Production of *m-th* lot of product *i*	
$\delta_{I,t}$= {0,1}: Indicates if product i is produced at t	$\varepsilon_{I,t}$ = {0,1}: Indicates if product i is set-up at t	
M_i: Number of lots of product i scheduled	$PP_{i,m}$: Order Point *m-th* lot of product *i*	
$S_{i,t}$: stock hold of product I at start of period t		

Figure 1. Notation used in this paper

Set of constraints [c.1.1] establishes the material balance along the different periods. The inventory level can not be neither lower than the estimated period demand nor upper than warehouse capacity (constraints [c.1.5] and [c.1.6]).

[c.1.2] bounds the use of common resources, both for production and set-ups, trough binary variables, which are indicators of the item status for every item and period and defined at [c.1.3] and [c.1.4].

[c.1.7] prevents from programming two simultaneous lots of the same item, and [c.1.8] make lots to be allocated within the planning horizon. Finally [c.1.9] define the number of each item set-ups.

Decision variables are $Z_{i,m}$ and $Q_{i,m}$, since they indicate when is set up each item i lot and its lot size, being the rest of variables indicators. Trough these decision variables, the mentioned objective function should be minimized.

3. Resolution Methodology proposed

In the resolution methodology presented, the first of the three mentioned subfunctions basically implies the lots size definition. The second means the establishment of the sequence in which different items lots must be set up. Finally, the third one is Scheduling.

Before Scheduling, the feasibility of the results obtained for the two previous subfunctions must be verified. This can be done by means of an *Early Scheduling* in which every sequenced lot is scheduled as soon as possible. If any period, any item demand could not be satisfied, lot sizes would need a redefinition, what would led us to a new sequence whose feasibility should be verified again.

Once the Production Program obtained is feasible, with no stockout, a right Inventory Management would require a definition of a *Late Scheduling Program* which, starting with the last lot sequenced, would delay as much as possible the beginning of every setup without affecting to other items:

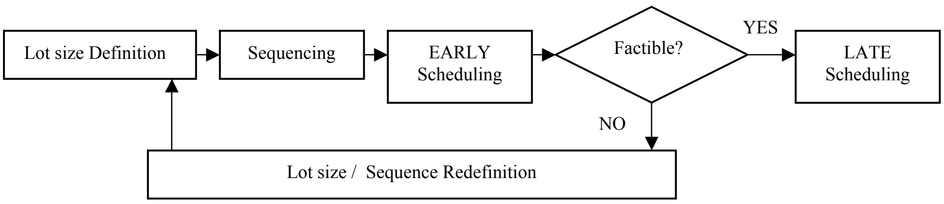

Figure 2. General Resolution Methodology

3.1 Lot size definition

Lot size definition is the first stage. We propose the following model to define a proposed lot size. Considering the real environment studied, where demand can be assumed as a predicted stable value ($d_{i,t}=d_i \ \forall t$) and where every productive unit will be only available during a certain ratio γ of the total horizon periods H (due to try outs, maintenance…); lots may be defined by:

$$[MIN] \sum_i \left[\frac{d_i}{Q_i} CL_i + h_i \frac{Q_i (p_i - d_i)}{2p_i} \right] \qquad [0.2.1]$$

Subject to:

$$\sum_i \left(\frac{d_i H}{Q_i} TL_i + \frac{d_i H}{p_i} \right) \leq \gamma H \qquad [c.2.1]$$

$$Q_i \frac{p_i - d_i}{p_i} + SS_i \leq MAX_i \quad \forall i \qquad [c.2.2]$$

3.2. Sequencing and Feasibility Analysing (Early Scheduling)

Once defined the lot size for every item, the proposed methodology has to sequence the orders. The rule will be to sequence first the item with an earlier order point, defined as:

$$PP_{i,m+1} = \frac{S_{i,0} + \sum_{j=1}^{m+1} Q_{i,j} - SS_i}{d_i} - TL_i \qquad (1)$$

If the minimum value thus obtained is upper than the time τ in which the productive unit will finish the last lot programmed then the process carries on. If not, for avoiding any stockout, some feedback heuristics rules are defined in order to reach a feasible Production Program. These rules include the lot size redefinition, the reorder of some lots, or both, depending on the criteria established by these rules.

3.3. Late Scheduling

With the Program obtained through the Early Scheduling step, stock level would clearly tend to raise. To avoid that we proceed with the Late Scheduling of the sequenced lots. This Scheduling starts with the last lot sequenced in previous step, delaying all set up points as much as possible, taking care of shared resources and feasibility that could affect to other items.

4. Evaluation of different rules on applying the Late Scheduling step

Applying this methodology to the real environment described, some experiments have been developed. Different heuristic rules for the Late Scheduling have been designed and applied to several real problems, obtaining many results that have been analysed. Some of these rules have shown themselves efficient, depending on the fixed objective to satisfy, minimizing its matching variables.

5. Conclusions

This paper shows the work developed for establishing the mathematical model of an Automotive Factory Press Shop system; the general resolution methodology applied for Production Programming; and different heuristic rules designed for its experimentation, whose efficiency level depends on the established criteria to optimise in every real case.

The proposed methodology has been implemented on a software that actually works on a real factory. Making daily the program with an horizon of two weeks,

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